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PLASMA WAVES AND RADIATION GENERATED NEAR THE TERMINATION SHOCK

Period: 5/1/93 - 4/30/94

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1 Introduction

NASA grant NAGW-3461, titled 'Plasma Waves and Radiation Generated Near the Termination Shock', started on 1 May 1993 with an anticipated 2 year duration under the direction of Principal Investigator Cairns. The grant supports a program of theoretical and interpretative investigations into the generation, characteristics and utility of the 2-3 kHz radio emissions observed in the outer heliosphere by the Voyager spacecraft. The original observations of these emissions were reported by Kurth et al. [1984]. The overall aims of the research program, as well as the personnel and methodology, were reviewed in the first semi-annual report (dated 23 November 1993). In brief, they involve (1) developing theories for the 2 kHz component and transient events that comprise the 2-3 kHz radiation, (2) distinguishing between whether the radiation originates near Jupiter or in the outer heliosphere, (3) determining more accurate methods for remotely inferring the locations of the termination shock and/or the heliopause, and (4) performing new data, interpretative and theoretical analyses of the radiation. Dr. Cairns receives 3 months of salary support from the grant, while Co-Investigators Kurth and Gurnett need no support. A significant amount of progress has been made towards fulfilling the project's aims during the grant's first year, as described below and in the November semi-annual progress report.

2 Progress made in the Grant's First Year

In 1992 and 1993 the Goddard Group of Kaiser, Desch and Farrell revived the question of whether the 2-3 kHz radio emissions originate in Jupiter's magnetosphere or the outer heliosphere. Comparisons between the Ulysses data and the recent 1992/93 Voyager radio event provide strong arguments against, and no arguments for, a Jovian source model [talks by Gurnett et al. in 1993]. It appears certain that the emissions are generated in the outer heliosphere. We regard the grant's aim 2 above as being satisfied.

Dr. Cairns collaborated with Dr.'s Zank, Donohue, and Matthaeus of the Bartol Research Institute on an alternative to the Gurnett et al. [1993] model for the emissions (radiation associated with a shock moving up a density pile-up region near the heliopause). This collaboration is motivated by difficulties with the Gurnett et al. [1993] model, including: (1) Why don't virtually all strong interplanetary shocks produce transient radio emissions? (2) Why does the radio emission turn on only at the heliopause? Rather than rely on density pile-up effects at the heliopause, the Zank et al. model relies heavily, instead, on the interaction of interplanetary shocks and density enhancements with a termination shock that is strongly modified by cosmic ray effects. The basis of the model is that these interactions with the termination shock produce significant density structures in the heliosheath, as shown in simulations by Donohue and Zank [1993]. The 2-3 kHz radiation is then interpreted in terms of $2f_p$ emission associated with a subsequent shock [e.g., Cairns and Gurnett, 1992; Cairns et al., 1992] that travels through the density structures in the heliosheath. Very recently a paper describing the model and associated results was revised and then accepted for publication in the Journal of Geophysical Research [Zank, Cairns, Donohue and Matthaeus, 1994]. A paper was also submitted to Nature, but received unfavorable comments from one referee and we judged it more efficient to drop the paper in favor of the accepted J.G.R. paper. (This work relates to aims 1, 3 and 4 of the grant.)

In addition, Dr. Cairns performed calculations on the angular broadening and related effects expected from 2-3 kHz radiation scattering off solar wind and heliosheath density irregularities (cf. aim 4). Familiar examples of such scattering include interplanetary scintillation (IPS) measurements and the angular and spectral broadening of astrophysical sources due to ionospheric, interplanetary and interstellar density turbulence. The calculations have very interesting results, including: (1) path lengths of 50 AU in the model solar wind density spectrum near the Voyager locations (obtained using two distinct methods for extrapolating observations near 1 AU) can explain the modulation patterns observed during Voyager roll maneuvers [Kurth et al., 1987; Gurnett et al., 1993]; (2) greatly increased scattering is expected in the cosmic ray foreshock and the downstream region (heliosheath) of the termination shock, based on analogies with Earth's bow shock, compared with the intrinsic scattering rates in the solar wind; (3) potential conflicts between the two proceeding results argue that further work on the spectrum of density turbulence and the scattering calculations must be performed; and lastly, (4) scattering effects should be fully considered when interpreting the directivity, spectral broadening and amplitude fluctuations of the observed 2-3 kHz radiation, rather than ignoring such effects. Writing up this preliminary work, and detailed extensions thereof, form the primary thrust of the research program proposed for the second year of the grant.

3 Research Projects for the Second Year

Current plans call for two research projects to be addressed in the grant's second year. Since both new projects are primarily theoretical and interpretative, Dr. Cairns will be the primary worker and Dr.'s Kurth and Gurnett are envisaged to spend little time on the research. They expect to undertake separate observational and interpretative projects on the 2-3 kHz emissions which will indirectly benefit this grant's research.

The first project will involve the effects of scattering by density irregularities on the directivity, amplitude, frequency spectrum and observability of the 2-3 kHz radio emissions. Such scattering effects may prove attractive means to explain (1) the different directivities found by Kurth et al. [1987] and Gurnett et al. [1993] for the Voyager radiation at 1.78 kHz and 3.11 kHz, (2) the rapidly changing source directions found by Gurnett et al. [1993] for the recent 1992/93 events, and (3) why the starting frequencies of the transient events vary widely (by a factor ~ 2). Likely research steps are:

1. Write up the scattering calculations performed to date, demonstrating results 1 and 2 in the previous section.

2. Extend the calculations and investigate whether the very high time resolution Voyager Wideband data can be used to infer the characteristics of the density turbulence and the unscattered characteristics of the radiation and its source. This will be done in partial collaboration with Dr. R.L. Mutel (University of Iowa), an expert on radio-astronomical scattering observations.

3. Collaborate with the MIT Voyager team or other scientists in obtaining the spectrum of solar wind density turbulence from *in situ* particle detectors, for comparison with the scattering work.

The second project will involve further collaboration with Dr. G.P. Zank (Bartol Research Institute) on the Zank et al. [1994] model for the radio emissions and their source. We have preliminary ideas on a means to trigger the radio emissions by increasing the number and energy of mildly superthermal electrons in the heliosheath. The ideas involve shock drift-accelerated electrons scattering back and forth between a moving interplanetary shock and the termination shock. We intend to quantitatively investigate our mechanism and to compare it with observational constraints.

4 References

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5 Publications Supported Directly in the Grant's First Year

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